BOTANICAL DERIVATIVES IN MOSQUITO CONTROL: A REVIEW[1]

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ABSTRACT. A review on the reported uses of chemicals derived from botanical sources is presented, along with the part of the plant used for extraction, the mosquito species studied and the bioactivity observed for 344 plant species. Examples of phytochemicals evaluated against mosquitoes as general toxicants, growth and reproduction inhibitors, repellents and ovipositional deterrents are given. The effects of mosquito species and life stage specificity, solvents used for extraction, phototoxic activity and the geographical source from where the plant compounds are derived are discussed.

INTRODUCTION

Phytochemicals derived from various botanical sources have provided numerous beneficial uses ranging from pharmaceuticals to insecticides. Synthetic organic insecticides, although highly efficacious against target species such as mosquitoes, can be detrimental to a variety of animal life including man (Matsumura 1975). In addition to adverse environmental effects from conventional insecticides, most major mosquito disease vector and pest species have become physiologically resistant to many of these compounds (Brown 1986). These factors have created the need for environmentally safe, degradable and target-specific insecticides against mosquitoes. The search for such compounds has been directed extensively to the plant kingdom.

Historically, the commercial development of botanical insecticides is credited to a lady of Ragusa, Dalmatia, who noticed dead insects on a discarded bouquet of pyrethrin flowers. She began milling pyrethrum into powder and thus the pyrethrin industry was born (Hartzell and Wilcoxon 1941). Since then, pyrethrins from chrysanthemum flowers and many synthetic derivatives stand prominent as effective pesticides.

One of the earliest reports of the use of plant extracts against mosquito larvae is credited to Campbell et al. (1933) who found that plant alkaloids like nicotine, anabasine, methyl anabasine and lupinine extracted from the Russian weed, *Anabasis aphylla*, killed larvae of *Culex pipiens* Linn., *Cx. territans* Walker, and *Cx. quinquefasciatus* Say. Haller (1940) noted that extracts from Amur cork tree fruit, *Phellodendron amurense*, yielded a quick-acting mosquito larvicide. Wilcoxon et al. (1940) reported that extracts derived from the male fern, *Aspidium filix-mas*, yielded a toxic constituent, filicin, a phloroglucinol propyl ketone, which proved toxic to *Cx. quinquefasciatus*. Hartzell and Wilcoxon (1941) evaluated extracts from 150 species of plants for their toxicity to mosquitoes and found several to be very effective. In an exhaustive review on insecticides derived from plants, covering a period from 1941 to 1953, Jacobson (1958) reported on several phytochemicals against mosquitoes.

Phytochemicals can be extracted from either whole plants or specific parts of the plant, depending on the activity of the derivatives. Some plants accumulate bioactive chemicals differentially in the various parts of the plant, such as leaves, fruits, flowers, roots and bark. Investigators have found that the effectiveness of chemicals derived from specific plant parts often varies with the mosquito species. Certain phytochemicals have photo-activated toxins that are reported effective against mosquitoes. Some phytochemicals act as general toxicants to all life stages of mosquitoes, whereas others interfere with growth and reproduction, or act on the olfactory receptors, eliciting responses of attractancy or repellency. In this review, the plants used for mosquito control, irrespective of their status as higher or lower plants, are arranged by families in alphabetical order. The part of the plant used for extraction, the mosquito species studied and the bioactivity observed have also been listed (Appendix 1).

TOXICITY EFFECTS

Many plant chemicals produce larvicidal, pupicidal and adulticidal effects, most behaving like general toxicants (Appendix 1). The differential responses induced by phytochemicals on various species of mosquitoes were influenced by extrinsic and intrinsic factors such as the species of plant, the parts of the plant, the solvents used for extractions, the geographical location where the plants were grown and the methods em-

[1] The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

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ployed for evaluation. Only a few examples will be discussed in any detail to illustrate these factors.

Extracts from different parts of the same species of plant can exhibit various degrees of toxicity to mosquitoes. Marcard et al. (1986) reported that among the different plant parts from *Ajuga remota* and *A. reptans*, the effectiveness of the derived extracts against *Aedes aegypti* (Linn.), *Ae. togoi* (Theobald) and *Cx. quinquefasciatus* larvae decreased with roots> leaves> shoots> and flowers, respectively. Extracts from 325 wild-growing plants of North Dakota and western Minnesota were found to have varied effects on the mortality of *Ae. aegypti* larvae by both plant species and the plant part of the same species (Patterson et al. 1975).

In certain instances, the same phytochemical toxin from a single plant species exhibits various degrees of toxicity to different mosquito species. Minijas and Sarda (1986) showed that crude extracts containing saponin from fruit pods of *Swartzia madagascariensis* produced higher mortality in larvae of *Anopheles gambiae* Giles than in larvae of *Ae. aegypti* and no mortality was induced in larvae of *Cx. quinquefasciatus*. Sujatha et al. (1988) also observed differential susceptibilities with petroleum ether extracts of *Acorus calamus*, *Ageratum conyzoides*, *Annona squamosa*, *Bambusa arundanasia*, *Madhuca longifolia* and *Citrus medica* against larvae of 3 species of mosquitoes. *Acorus calamus* extract, of the 6 extracts, was most effective against *Cx. quinquefasciatus* while *Bambusa arundanasia* was most toxic against *An. stephensi* Liston. *Citrus medica* extracts affected only *An. stephensi* larvae whereas *Madhuca longifolia* extracts had no effect on this species. Similarly, when extracts of the pond weeds *Myriophyllum* and *Potamogeton* were assayed against larvae of *An. occidentalis* Dyar and Knab and *Cx. pipiens*, *Cx. pipiens* showed more resistance to both extracts (Graham and Schooley 1984). Such a differential species susceptibility was also noticed by Dhillon et al. (1982) when algal toxins from *Rhizoctonium heiroglyphicum* and *Chlorella ellipsoidea* were assayed against *Ae. aegypti*, *Cx. quinquefasciatus* and *Culiseta incidens* (Thomson). Of the 3 species of mosquito larvae tested, *Cx. incidens* was found to be the most susceptible and *Cx. quinquefasciatus* the least susceptible to *Rhizoclonium* extracts. The *Chlorella* extracts appeared more toxic to *Cx. quinquefasciatus* and *Cx. incidens* than to *Ae. aegypti*. When several volatile plant oils were assayed against the larvae of *An. claviger* (Meigen) and *Ae. cantans* (Meigen), the results showed that anophelines were less sensitive than aedines (Novak 1985). Saxena and Sumithra (1989) found the leaf extract of *Ipomea carneafistolosa* most effective against *An. stephensi* when they tested the extract against larvae and pupae of *An. stephensi*, *Ae. aegypti* and *Cx. quinquefasciatus*.

At times, certain stages of mosquitoes are more susceptible to phytochemicals. Osmani and Sighamony (1980) found that the oil of lemongrass (*Cymbopogon citratus*), oil of linaloe (*Bursera delpechiana*) and oil of geranium (*Pelargonium roseum*) were poor ovicides and had no effect on first instar larvae, but did cause significant growth inhibition and mortality in later developmental stages of *Ae. aegypti*. A butanol extract of soapberry plant, *Phytolacca dodecandra*, was very toxic to second and third instar larvae of *Ae. aegypti*, *Cx. pipiens molestus* Förskal (= *Cx. pipiens*) and *An. quadrimaculatus* Say, but eggs and pupae were unaffected and adults died only after ingestion of the concentrated extract (Spielman and Lemma 1973). Likewise, the ethanolic extracts of *Haplophyllum tuberculatum* did not produce any ovicidal effect, but killed first instar larvae of *Cx. quinquefasciatus* (Mohsen et al. 1989). The latex from *Calotropis procera* showed complete ovicidal and larvicidal effects on *Aedes*, *Anopheles* and *Culex* but had no effects on adults of these genera.

The extraction of the plant chemicals with specific solvents exerts a great influence in the resultant bioactivity. It could be possible that the active constituent responsible for activity is extracted in greater measures only with certain solvents. When *Macrocystis pyrifera* and *Artemesia cana* were extracted with water and with organic solvents, the latter extract produced higher mortality in *Cx. quinquefasciatus* (Sherif and Hall 1985). This could have been due to the polarity range of the solvents. Hartzell (1944) tested acetone extracts and water extracts of certain plant products against *Cx. quinquefasciatus* larvae and found acetone to be a better solvent. Extracts of roots of *Derris elliptica*, when bioassayed against fourth instar larvae of *Ae. aegypti*, exhibited a response indicating that among the liquid extracts, absolute ethyl alcohol was the most potent, and among the crude residues acetone extract was the most effective (Ameen et al. 1983, 1985). The commercial oil of *Linum usitatissimum* had no apparent toxic effects on *Cx. pipiens* larvae, but the crude methanolic extract showed limited toxicity (Banu and Nurul-Huda 1983). Dhillon et al. (1982) found petroleum ether extracts of *Chlorella ellipsoidea* and *Rhizoctonium heireoglyphicum* eluted with petroleum ether, benzene or methanol, all induced mortality in *Ae. aegypti* and *Cx. quinquefasciatus*, with the methanol fraction being the most active. Bioassay of *Aloe puridens* roots extracted with solvents of increasing polarity showed that the petroleum ether extract pos-

sessed the maximum insecticidal activity against *Ae. aegypti* larvae (Confalone et al. 1983). Qureshi et al. (1986) assayed alcoholic extracts and petroleum ether extracts of *Ervatamia coronaria* against fourth instar larvae of *Ae. aegypti* and found the alcoholic extracts to be highly toxic whereas the petroleum ether extract had no larvicidal activity. But in the case of *Acorus calamus*, when the rhizomes were extracted with different solvents like petroleum ether, ether, chloroform and alcohol, the best results against *Cx. quinquefasciatus* larvae were obtained with the petroleum ether extract (Chavan et al. 1979). According to the bioassay results against *Ae. aegypti* larvae, with different extracts of *Lithospermum arvense*, the active principle was concentrated mainly in the hexane-soluble portion (Madrigal et al. 1979).

Certain plant derivatives showed enhanced action in the presence of light. As Arnason et al. (1981) observed, light has often been a forgotten or underestimated factor in the study of insects. Until recently, little attention has been paid to its role in plant-insect reactions. The activation of plant secondary substances by light, and their subsequent photosensitizing effects on insects, especially mosquito larvae, is an important factor contributing to the enhancement of toxicity. Polyacetylenes and thiophenes that occur in certain plants of the Asteraceae family show the greatest potential as photoactive pest control agents. The common marigold, *Tagetes* sp., yielded a highly active polyacetylene alpha-terthienyl from its roots, which proved very toxic to *Ae. aegypti* larvae (Arnason et al. 1981, Kagan et al. 1987). The activity increased with light, indicating a phototoxic action of alpha-terthienyl. Berberine, an isoquinoline alkaloid present in many different plant families, is also photoactivated. Larval, pupal and adult survival of *Ae. atropalpus* (Coq.) was affected by berberine treatment with toxicity of the alkaloid increasing after exposure to light. Philogene et al. (1984) speculated that the fluorescent nature of berberine could be the reason for its photodynamic activity. Rose bengal, a xanthene-derivative, also causes enhanced mortality in mosquito larvae by photosensitized oxidation reactions. Its primary mode of action depends on the absorption of visible light energy, causing photooxidative toxicity (Pimprikar et al. 1979).

The geographical distribution of plants may possibly influence their toxicity. Novak (1985) did not observe any toxicity with acetone and alcohol extracts of garlic, *Allium sativum*, in *Aedes* larvae when tested in Czechoslovakia, but Amonkar and Reeves (1970) in the USA reported that the extracted oil and crude methanolic extract of garlic at very low concentrations could control larval mosquitoes of 5 species. Likewise, Jacobson (1958) reported that acetone extracts of *Vetiveria zizanoides* roots from the USA failed to induce larval toxicity, but Murthy and Jamil (1987) found the oil of *Vetiveria* roots from India very effective against *Cx. quinquefasciatus* larvae. Although it is not clear in the above cases whether the geographic origin of the plant material or the difference in solvents used for extraction of the material is contributing to the differential toxicity, it suggests that further investigation is needed.

GROWTH AND REPRODUCTIVE INHIBITION

By and large, plant chemicals act as general toxicants. A few, however, show selective interference with growth and reproduction. Precocene from *Ageratum* was noted for its unique action of interfering with growth by transgressing certain stages of development. In mosquitoes, it prevented pupal formation and adult emergence when newly hatched young larvae were exposed (Cupp et al. 1977). When females were treated with precocene after blood feeding, it inhibited trypsin synthesis, retarding ovarian maturation, resulting in abnormal oviposition (Kelly and Fuchs 1978). Some other plant chemicals, such as aristolochic acid from *Aristolochia bracteata*, inhibited reproduction, inducing sterility in mosquitoes (Saxena et al. 1979). Biotin from plants, aflatoxin from *Aspergillus flavus* and pactamycin and porfiromycin from lower plants have also sterilized mosquitoes (Borkovec 1987).

Although numerous plants have shown tendencies to interfere with growth and reproduction, neem (*Azadirachta indica*) occupies an important place because of its strong action in inducing toxicity through inhibition of growth and reproduction. Although the exact mode of action of azadirachtin and other components present in neem seed kernels is not clearly understood, it seems likely that there is an interference in hormonal balance. Zebitz (1984) suggests that azadirachtin acts as an anti-ecdysteroid or affects the neuroendocrine control of the ecdysteroids. The unique mode of action of azadirachtin, by its controlling effect on hormones and its favorable toxicological and selective properties from the ecological perspectives, provides a basis for emergence of a promising phytochemical in mosquito control.

Patterson et al. (1975) found that extracts from several plants of North Dakota exhibit mimics of insect ecdysones and juvenile hormone activity at various levels based on the parts of the plant used for extraction. As with toxicity, growth inhibition from phytochemicals can also be species specific. Sujatha et al. (1988)

observed that *Acorus calamus* extracts induced malformations to a greater extent in *An. stephensi* and to a lesser extent in *Cx. quinquefasciatus* and *Ae. aegypti*, while *Madhuca longifolia* induced greater growth inhibition in *Cx. quinquefasciatus*.

Growth and reproductive inhibition effects from phytochemicals are also affected by the solvent used in the extraction process. Only the methanol-eluted fraction of petroleum ether extracts from the filamentous algae *Rhizoclonium heiroglyphicum* exhibited insect growth inhibitory activity and various abnormalities in eclosing *Ae. aegypti*, *Cx. quinquefasciatus* and *Culiseta incidens* adults (Dhillon et al. 1982).

REPELLENCY AND OVIPOSITIONAL DETERRENTS

The use of phytochemicals as repellents, ovipositional deterrents and antifeedants has been evaluated against both agricultural pests and medically important insect species (Jacobson 1958). Thorsell et al. (1970) reported that extracts from 3 plant species, *Ledum palustre*, *Lycopersicon lycopersicon* and *Myrica gale*, exhibited repellency to *Ae. aegypti* adults. The essential oils of certain plants often exhibit repellent actions to mosquitoes, as shown with the leaf oil of *Ocimum suave* (Chogo and Crank 1981).

In addition to repellency, phytochemicals can influence the ovipositional behavior of mosquitoes. Consoli et al. (1989) found ethanolic, hexanic and lyophilized extracts of 8 plants (*Allium sativum*, *Anacardium occidentale*, *Bidens segetum*, *Caesalpinia peltophoroides*, *Jatropha curcas*, *Mikania schenkii*, *Poinciana regia* and *Spatodea campanulata*) deter oviposition by *Ae. fluviatilis* (Lutz). Acetone extracts of 4 species of the Labiatae family are reported ovipositional deterrents to *Ae. aegypti* (Sharma et al. 1981b), with one species, *Lavendula gibsonii*, having also an ovicidal and general repellent effect on *Ae. aegypti* (Sharma et al. 1981a).

The factors of species specificity and the solvent used for extraction are components that can affect ovipositional deterrence from phytochemicals. Aqueous extracts of *Lemna minor* significantly deterred oviposition by *Ae. aegypti*, but had no effect against *Cx. pipiens* (Judd and Borden 1980). The methanolic extract of the same plant also deterred oviposition in *Ae. aegypti*, but the pentane extract showed no ovipositional deterrent activity. Judd and Borden (1980) theorized from the results of significant ovipositional deterrent activity of the aqueous and methanolic extracts that the active principles are of a polar nature. The need for further investigation of phytochemicals as repellents and deterrents against mosquitoes has been stated by Novak (1985) in his review of nonchemical approaches to mosquito control in Czechoslovakia.

CONCLUSION

Chemicals derived from plants offer promise in future mosquito control programs. In addition to application as general toxicants against various life stages of mosquitoes, phytochemicals also have potential uses as growth and reproduction inhibitors, repellents and as ovipositional deterrents. Many research opportunities exist in the identification and characterization of new plant compounds, as well as in the evaluation of their ecological, evolutionary and physiological significances. Research on the use of phytochemicals against mosquitoes should consider such factors as mosquito species, life stage specificity to a compound, the plant parts and solvent used for extraction, phototoxic activity and the geographical origin of a plant compound.

Phytochemicals offer not only effective mosquito control agents, but also are biorational alternatives to organic synthetic pesticides. The fact these chemicals are from natural sources, with a high degree of biodegradation, makes them environmentally sound control agents. With an ever increasing public interest and awareness in the environment, in both developed and developing countries, positive public perception of natural pesticides is an added incentive for their development and use. In addition, the potential use of phytochemicals from botanical species in the endangered rainforest regions of the world offers economical and practical reasons for their preservations.

The same public perception can also have a negative effect in the utilization of phytochemicals, due to their often slower and nontoxic control effects on mosquitoes compared with conventional insecticides. People have become accustomed to the immediate toxic effects of synthetic insecticides. With phytochemicals' slower modes of action, people believe that they are not effective and discontinue their use. Education of the public is critical if phytochemicals can be effectively utilized in mosquito control programs.

Several botanicals offer great promise as sources of phytochemicals for the control of mosquitoes. Six plant families with several representative species, Asteracae, Cladophoraceae, Labiatae, Meliaceae, Oocystaceae and Rutaceae, appear to have the greatest potential for providing future mosquito control agents. Some of

these new compounds with their novel modes of bioactivity may prove useful in the development of safer insecticides for the future.

ACKNOWLEDGMENTS

We acknowledge the able assistance of Joan Auch, Gina M. Pishioneri, Mary A. Hathaway, Melba D. Ashby and Brett W. Collier in manuscript preparation. The efforts of Raj K. Gupta, Robert S. Edgecomb, Bobbie L. Bunner and Gunda Reddy in reviewing the manuscript are also greatly appreciated.

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Appendix 1. Reported botanical extracts against various mosquitoes alphabetically arranged by plant family.

Family and species[a]	Parts used	Mosquito species	Bioactivity	Reference
ACANTHACEAE				
Aldleathoda species	Whole plants	*Ae. aegypti* *Cx. quinquefasciatus* *An. stephensi*	Larvicidal	Kalyanasundaram and Das (1985)
AGARICACEAE				
Amanita muscaria	Whole plants	*Aedes* species	Larvicidal	Jacobson (1958)
A. pantherina	Whole plants	*Cx. pipiens*	Larvicidal	Jacobson (1958)
Lepiota procera	Whole plants	*Cx. pipiens*	Larvicidal	Jacobson (1958)
AGAVACEAE				
Agave americana	Leaves, seeds	*Ae. aegypti* *An. stephensi* *Cx. quinquefasciatus* *Ae. fluviatilis*	Larvicidal	Dharmashaktu et al. (1987), Consoli et al. (1988)
ANACARDIACEAE				
Anacardium occidentale	Seed shells, rind of fruits, nut husks	*Cx. quinquefasciatus* *Ae. fluviatilis* *An. arabiensis*	Larvicidal, repellent, ovipositional deterrent	Evans and Kaleysa Raj (1988), Consoli et al. (1988, 1989), Carrara et al. (1984)
ANNONACEAE				
Annona cherimola	Seeds	*Aedes* species	Larvicidal	Jacobson (1958)
A. glabra	Seeds	*Aedes* species	Larvicidal	Jacobson (1958)
A. squamosa	Seeds, leaves, stems, roots	*Ae. aegypti* *An. stephensi* *Cx. quinquefasciatus*	Larvicidal, growth inhibition	Jacobson (1958), Sujatha et al. (1988)
APOCYNACEAE				
Apocynum androsaemifolium	Stems, leaves, roots, flowers	*Ae. aegypti*	Larvicidal, growth inhibition	Patterson et al. (1975)
Ervatamia coronaria	Whole plants	*Ae. aegypti*	Larvicidal, growth inhibition	Qureshi et al. (1986)
Malouetia obtusiloba	Branchlets, leaves, bark	*Aedes* species *Anopheles* species	Larvicidal	Jacobson (1958)
Nerium indicum	Leaves, roots	*Cx. quinquefasciatus*	Larvicidal	Chavan and Nikam (1983), Evans and Kaleysa Raj (1988)
N. oleander	Stems, leaves	*Ae. fluviatilis*	Larvicidal	Consoli et al. (1988)

Rauvolfia canescens	Whole plants	*Ae. aegypti* *Cx. quinquefasciatus* *An. stephensi*	Larvicidal	Kalyanasundaram and Das (1985)
Thevetia nerifolia	Cotyledons	*Cx. quinquefasciatus*	Larvicidal	Evans and Kaleysa Raj (1988)
Vinca rosea	Whole plants	*Ae. aegypti* *Cx. quinquefasciatus* *An. stephensi*	Larvicidal	Kalyanasundaram and Das (1985)
ARACEAE				
Acorus calamus	Roots, rhizomes, whole plants	*Anopheles* species *Ae. aegypti* *Cx. quinquefasciatus*	Adulticidal, repellent, larvicidal, growth inhibition	Jacobson (1958), Dixit et al. (1965), Chavan et al. (1976, 1979), Deshmukh and Renapurkar (1987), Sujatha et al. (1988)
Symphalocarpus foetidus	Roots	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
Syngonium podophyllum	Stems, leaves	*Aedes* species	Larvicidal	Jacobson (1958)
ARISTOLOCHIACEAE				
Aristolochia bracteata	Stems, leaves, aristolochic acid from plant	Mosquito larvae *Ae. aegypti*	Larvicidal, sex sterilant	Jacobson (1958), Saxena et al. (1979)
ASCLEPIADACEAE				
Asclepias speciosa	Roots, rhizomes, leaves, flowers, fruits	*Ae. aegypti*	Larvicidal, growth inhibition	Patterson et al. (1975)
A. syriaca	Whole plants	*Ae. aegypti*	Larvicidal, growth inhibition	Supavarn et al. (1974)
Calotropis species	Whole plants	*Ae. aegypti* *Cx. quinquefasciatus* *An. stephensi*	Larvicidal	Kalyanasundaram and Das (1985)
Calotropis gigantea	Some parts of the plant as dusts or extracts	Mosquito larvae	Larvicidal	Jacobson (1958)
C. procera	Latex from leaves	*Ae. aegypti* *An. stephensi* *Cx. quinquefasciatus*	Larvicidal, ovicidal	Giridhar et al. (1984)

Appendix 1. *Continued.*

Family and species[a]	Parts used	Mosquito species	Bioactivity	Reference
ASTERACEAE				
Achillea millefolium	Whole plants	*Aedes* species *Ae. aegypti* *Ae. triseriatis*	Larvicidal	Supavarn et al. (1974), Gayar and Shazli (1968), Lalonde et al. (1980)
Ageratum conyzoides	Leaves, stems roots, seeds (Precocene II)	*Ae. aegypti* *An. stephensi* *Cx. quinquefasciatus*	Larvicidal, growth inhibition, toxicity and abnormal oviposition	Sujatha et al. (1988), Kelly and Fuchs (1978), Cupp et al. (1977)
Ambrosia cumanensis	Some plant parts as dust or extracts	Mosquito larvae	Larvicidal	Jacobson (1958)
A. psilostachya	Roots	*Anopheles* species	Larvicidal	Jacobson (1958)
Artemesia species	Plant oil	*An. stephensi*	Larvicidal	Khand and Qadri (1974)
A. cana	Whole plants	*Cx. quinquefasciatus* *Cx. tarsalis* *Ae. aegypti*	Growth inhibition, larvicidal, ovipositional deterrent, toxicant, repellent	Sherif and Hall (1984, 1985)
A. vulgaris	Whole plants, twigs	*Ae. aegypti* *Cx. quinquefasciatus*	Repellent, growth inhibition	Hwang et al. (1985), Deshmukh and Renapurkar (1987)
Bidens segetum	Whole plants	*Ae. fluviatilus*	Ovipositional deterrent	Consoli et al. (1989)
Blumea eriantha *B. oxydonta*	Leaves	*Cx. pipiens*	Larvicidal	Dongre and Rahalkar (1980)
Brauneria species	Roots	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
Cacalia tuberosa	Some plant parts, dusts or extracts	Mosquito larvae	Larvicidal	Jacobson (1958)
Chrysanthemum balsamita	Leaves	Mosquito larvae	Larvicidal	Hartzell (1944)
Cichorium pumillum	Whole plants	*Cx. pipiens*	Larvicidal	Gayar and Shazli (1968)
Clibodium erosum	Fruits, seeds	Mosquito larvae	Larvicidal	Jacobson (1958)
C. surinamense	Some parts of plant as dusts or extracts	Mosquito larvae	Larvicidal	Jacobson (1958)

Eupatorium maculatum	Stems, leaves, roots, flowers, fruits	*Ae. aegypti*	Larvicidal, growth inhibition	Patterson et al. (1975)
Grindelia species	Whole plants	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
Gutierretia sarothrae	Whole plants	*Ae. aegypti*	Larvicidal	Supavarn et al. (1974)
Heliopsis longipes	Roots	*Aedes* species *Anopheles* species	Adulticidal, larvicidal	Jacobson (1958)
Hemizonia fitchii	Plant oil	*Ae. aegypti*	Ovipositional deterrent, repellent	Klocke et al. (1987)
H. pitchii	Whole plants	*Cx. pipiens*	Larvicidal	Klocke et al. (1985)
Hymenoclea salsola	Dried aerial parts	*Ae. atropalpus*	Growth inhibition	Arnason et al. (1985)
Inula helenium	Roots	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
Matricaria chamomilla	Whole plants, disc flowers	*Cx. quinquefasciatus* *Ae. aegypti*	Larvicidal, repellent	Gayar and Shazli (1968), Thorsell (1988), Sherif and Hall (1985)
Mikania schenki	Stems, leaves	*Ae. fluviatilus*	Ovipositional deterrent	Consoli et al. (1989)
Oligochaeta ramosa	Whole plants	*Ae. aegypti*	Larvicidal, pupicidal, growth inhibition	Saxena and Yadav (1983)
Parthenium hysterophorus	Whole plants, dried shoots	*Ae. aegypti* *Cx. quinquefasciatus* *An. stephensi* *Ae. atropalpus*	Larvicidal, growth inhibition	Kalyanasundaram and Das (1985), Sharma and Joshi (1977), Arnason et al. (1985)
Salmea scandens	Stems	Mosquito larvae	Larvicidal	Jacobson (1958)
Spilanthes acmella	Flowering tops	*Anopheles* species	Larvicidal, pupicidal	Jacobson (1958)
S. mauritiana	Fresh vegetative aerial parts	*Ae. aegypti*	Larvicidal	Jondiko (1986)
Tagetes erecta	Whole plants	*Cx. tritaeniorhynchus*	Larvicidal	Singh et al. (1987)
T. minuta	Fresh leaves, flowers	*Ae. aegypti*	Larvicidal	Marudufu et al. (1978)
Tagetes species	Roots	*Ae. aegypti*	Larvicidal (phototoxic)	Arnason et al. (1981)
Tussilago farfara	Roots	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
Vernonia salzamanni	Stems, leaves	*Ae. fluviatilis*	Larvicidal	Consoli et al. (1988)

Appendix 1. *Continued.*

Family and species[a]	Parts used	Mosquito species	Bioactivity	Reference
Xanthium spinosum	Flower tops, leaves	*Aedes* species	Larvicidal	Jacobson (1958)
BERBERIDACEAE				
Berberis aristata	Stems	Mosquito larvae	Larvicidal	Jacobson (1958)
Berberis species	Roots	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
BETULACEAE				
Betula mandschurica	Bark	*Cx. pipiens*	Larvicidal	Jacobson (1958)
Ostrya virginiana	Wood	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
BIGNONIACEAE				
Jacaranda filicifolia	Some plant parts as dusts or extracts	Mosquitoes	Adulticidal	Jacobson (1958)
Spatodea campanulata	Flowers	*Ae. fluviatilis*	Larvicidal, ovipositional deterrent at high concentrations, attractant at low concentrations	Consoli et al. (1988, 1989)
BIXACEAE				
Bixa orellana	Seeds, fruit pulp	Mosquitoes	Repellent	Mom (1948), Jacobson (1958)
BORAGINACEAE				
Borago officinalis	Whole plants	*Ae. aegypti*	Larvicidal, growth inhibition	Supavarn et al. (1974)
Lithospermum arvense	Whole plants	*Ae. aegypti*	Larvicidal, growth inhibition, reduction in adult emergence	Supavarn et al. (1974), Madrigal et al. (1979)
BURSERACEAE				
Bursera delpechiana	Plant oil	*Ae. aegypti*	Larvicidal, growth inhibition	Osmani and Sighamony (1980)
CALLITRICHACEAE				
Callitriche palustris	Whole plants	*Ae. aegypti*	Larvicidal, ovipositional deterrent	Angerilli (1980)
CAPPARACEAE				
Cleome psoraleafolia and *C. spinosa*	Some plant parts as dusts or extracts	Mosquito larvae	Larvicidal	Jacobson (1958)

C. viscosa	Whole plants	*Cx. quinquefasciatus*	Larvicidal	Kalyanasundaram and Babu (1982)
CAPRIFOLIACEAE				
Sambucus canadensis and *S. nigra*	Roots	*Cx. quinquefasciatus*	Larvicidal	Jacobson (1958)
CARICACEAE				
Carica papaya	Cell sap from fruits	*Cx. quinquefasciatus*	Larvicidal	Evans and Kaleysa Raj (1988)
CARYOPHYLLACEAE				
Gypsophila paniculata	Stems, leaves, flowers, fruits, roots	*Ae. aegypti*	Larvicidal, growth inhibition	Patterson et al. (1975)
Lychnis alba	Stems, leaves, flowers, fruits, roots, whole plants	*Ae. aegypti*	Larvicidal, growth inhibition	Supavarn et al. (1974), Patterson et al. (1975)
L. coronaria	Whole plants	*Cx. quinquefasciatus*	Larvicidal	Jacobson (1958)
Silene antirrhina	Whole plants	*Ae. aegypti*	Growth inhibition	Supavarn et al. (1974)
Vaccaria pyramidata	Plant saponin	*Ae. aegypti*	Growth inhibition	Harley (1967)
CERATOPHYLLACEAE				
Ceratophyllum demersum	Whole plants	*Ae. aegypti*	Larvicidal, ovipositional deterrent	Angerilli (1980)
CHARACEAE				
Chara globularis	Whole plants	*Ae. aegypti*	Larvicidal, ovipositional attractant	Angerilli (1980)
C. zeylanica	Stems, leaves	*Ae. fluviatilis*	Ovipositional attractant	Consoli et al. (1989)
CHENOPODIACEAE				
Anabasis aphylla	Whole plants	*Cx. pipiens* *Cx. territans* *Cx. quinquefasciatus* *Anopheles* species	Larvicidal, repellent	Campbell et al. (1933), Nobokov (1945)
Chenopodium ambrosioides	Some plant parts as dusts, extracts, whole plants	Mosquito larvae *Ae. aegypti*	Larvicidal, growth inhibition	Jacobson (1958), Supavarn et al. (1974)

Appendix 1. *Continued.*

Family and species[a]	Parts used	Mosquito species	Bioactivity	Reference
Suaeda maritima	Whole plants	*An. stephensi*	Larvicidal	Thangam and Kathiresan (1988a)
CLADOPHORACEAE				
Cladophora glomerata	Whole plants	*Ae. triseriatus*	Larvicidal	Lalonde et al. (1979)
Rhizoclonium herioglyphicum	Whole plants	*Cx. quinquefasciatus* *Cs. incidens* *Ae. aegypti*	Larvicidal, growth inhibition	Dhillon and Mulla (1981)
CLUSIACEAE				
Mammea americana	Seeds, stems, roots	Larvae of many species, *Anopheles* species	Larvicidal	Jacobson (1958)
CONVOLVULACEAE				
Convolvulus arvensis	Stems, roots leaves, fruits	*Ae. aegypti*	Larvicidal, growth inhibition	Patterson et al. (1975)
Cuscuta americana	Stems, flowers	*Aedes* species	Larvicidal	Jacobson (1958)
Ipomea jalapa	Roots	Mosquito larvae	Larvicidal	Hartzell (1944)
I. carneafistilosa	Leaves	*Cx. quinquefasciatus* *An. stephensi* *Ae. aegypti*	Larvicidal, growth inhibition	Saxena and Sumithra (1985, 1989)
CORIARIACEAE				
Coriaria japonica	Fruits	*Cx. pipiens*	Larvicidal	Jacobson (1958)
CORNACEAE				
Cornus florida	Leaves	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
CRUCIFERAE				
Armoracia rusticana	Fresh roots	*Cx. pipiens*	Larvicidal at autumn	Novak (1968, 1974)
Barbarea vulgaris	Whole plants	*Ae. aegypti*	Reduction of adult emergence	Supavarn et al. (1974)
Brassica nigra	Whole plants, seeds	*Cx. quinquefasciatus* *Ae. aegypti*	Larvicidal, reduction of adult emergence	Hartzell and Wilcoxon (1941), Supavarn et al. (1974)
Conringia orientalis	Stems, leaves, flowers, fruits	*Ae. aegypti*	Larvicidal, growth inhibition	Patterson et al. (1975)
CUCURBITACEAE				
Citrullus vulgaris	Seeds	*Cx. quinquefasciatus*	Larvicidal	Hartzell (1944)
Cucumis sativus	Seeds	*Cx. quinquefasciatus*	Larvicidal	Hartzell (1944)
Cucurbita pepo	Seeds	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)

Lepidium campestre *L. virginicum*	Whole plants	*Ae. aegypti*	Larvicidal, growth inhibition	Supavarn et al. (1974)
Raphanus sativus *Thlaspi arvense*	Whole plants	*Ae. aegypti*	Reduction of adult emergence	Supavarn et al. (1974)
DICTYOTACEAE				
Dictyola dichotoma	Whole plants	*An. stephensi* *Cx. quinquefasciatus*	Larvicidal	Thangam and Kathiresan (1988b)
EBENACEAE				
Diospyros maritima	Bark	Mosquito larvae	Larvicidal	Jacobson (1958)
ERICACEAE				
Eubotryoides grayana	Leaves	*Cx. pipiens*	Larvicidal	Jacobson (1958)
Ledum palustre	Whole plants	*Ae. aegypti*	Repellent	Thorsell et al. (1970)
Pieris japonica	Leaves	*Cx. pipiens*	Larvicidal	Jacobson (1958)
EUPHORBIACEAE				
Croton sparsiflorus	Whole plants	*Cx. quinquefasciatus* *Ae. aegypti* *An. stephensi*	Larvicidal	Kalyanasundaram and Das (1985)
C. tiglium	Seed oil, extract and resin from seeds	*Cx. pipiens* Mosquito larvae	Larvicidal	Marshall et al. (1985), Jacobson (1958)
Euphorbia dendroides *E. intisy* *E. ipecacuanhae* *E. peplus*	Leaves, seed oil, roots whole plants	Mosquito larvae *Cx. pipiens*	Larvicidal	Jacobson (1958), Gayar et al. (1971)
Hevea brasilianensis	Cotyledons	*Cx. quinquefasciatus*	Larvicidal	Evans and Kaleysa Raj (1988)
Hippomane mancinella	Bark and burrs	Mosquito larvae	Larvicidal	Jacobson (1958)
Hura crepitans	Leaves, roots, green fruits, ripe fruits, seeds	Mosquito larvae	Larvicidal	Jacobson (1958)
H. polyandra	Seeds, plant sap	Mosquito larvae	Larvicidal	Jacobson (1958)
Jatropha curcas	Some plant parts as dusts, extracts, fruits, leaves	Mosquito larvae *Ae. fluviatilis*	Larvicidal, oviposition deterrent	Jacobson (1958), Consoli et al. (1989)

Appendix 1. *Continued.*

Family and species[a]	Parts used	Mosquito species	Bioactivity	Reference
J. gossypifolia	Some plant parts as dusts, extracts	Mosquito larvae	Larvicidal	Jacobson (1958)
Phyllanthus acuminatus	Some plant parts as dusts, extracts	Mosquito larvae	Larvicidal	Jacobson (1958)
Ricinus communis	Whole plants, seed oil, plant oil	Mosquito larvae *Ae. aegypti* *An. stephensi*	Larvicidal, repellent, growth inhibition	Novak (1968), Supavarn et al. (1974), Anwarullah et al. (1970), Kumar and Dutta (1987)
FLACOURTIACEAE				
Ryania speciosa	Stems	*Aedes* species	Adulticidal	Jacobson (1958)
GERANIACEAE				
Geranium species	Whole plants	*Ae. aegypti*	Reduction of adult emergence	Supavarn et al. (1974)
Pelargonium roseum	Plant oil	*Ae. aegypti*	Larvicidal	Osmani and Sighamony (1980)
P. odoratissimum	Plant oil	*Cx. quinquefasciatus*	Repellent	Osmani et al. (1972)
GRAMINEAE				
Agropyron repens	Whole plants	*Ae. aegypti*	Larvicidal	Supavarn et al. (1974)
Andropogon martini	Plant oil	*Cx. quinquefasciatus*	Repellent	Osmani et al. (1972)
Avena sativa	Seeds	*Cx. quinquefasciatus*	Larvicidal	Hartzell (1977)
Bambusa arundanasia	Leaves, stems seeds, roots	*Cx. quinquefasciatus* *Ae. aegypti* *An. stephensi*	Larvicidal	Sujatha et al. (1988)
Cymbopogon citratus	Plant juice, plant oil	Mosquito adults *Ae. aegypti*	Larvicidal, repellent	Jacobson (1958), Osmani and Sighamony (1980)
C. nardus	Plant oil	*Aedes* species *Cx. quinquefasciatus* *An. stephensi*	Larvicidal, repellent	Jacobson (1958), Osmani et al. (1972), Kumar and Dutta (1987)
C. martinii	Plant oil	*An. stephensi* *Cx. quinquefasciatus*	Larvicidal, repellent	Kumar and Dutta (1987), Osmani et al. (1972)
C. flexuosus	Plant oil	*An. stephensi*	Larvicidal	Kumar and Dutta (1987)
Vetiveria zizanioides	Root oil	*Cx. quinquefasciatus*	Larvicidal	Murthy and Jamil (1987)

HALORAGACEAE				
Myriophyllum spicatum	Whole plants	*An. occidentalis* *Cx. pipiens* *Cx. quinquefasciatus* *Cx. tarsalis* *Cs. incidens* *Ae. aegypti*	Larvicidal, pupicidal, adult attractant	Graham and Schooley (1984), Dhillon et al. (1982), Schultz et al. (1983)
HYDROCHARITACEAE				
Elodea canadensis	Whole plants	*Ae. aegypti*	Larvicidal, ovipositional deterrent	Angerilli (1980)
E. nuttali	Whole plants	*Cx. quinquefasciatus*	Larvicidal, growth inhibition	Sherif et al. (1985)
JUGLANDACEAE				
Juglans cinerea	Bark of roots	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
LABIATAE				
Ajuga remota *A. reptans*	Roots, leaves, shoots, flowers	*Ae. aegypti* *Ae. togoi* *Cx. quinquefasciatus*	Larvicidal, growth inhibition	Marcard et al. (1986)
Anisomeles malabarica	Whole plants	*Ae. aegypti*	Ovipositional deterrent	Sharma et al. (1981b)
Hyptis suaveolens	Whole plants	*Ae. aegypti*	Reduction of adult emergence	Supavarn et al. (1974)
Lavandula bipinnata *L. gibsoni*	Whole plants	*Ae. aegypti*	Ovicidal ovipositional deterrent	Sharma et al. (1981a, 1981b)
L. officinalis	Plant oil	*An. stephensi*	Larvicidal	Kumar and Dutta (1987)
Majorana hortensis	Plant oil	*Ae. aegypti*	Larvicidal, growth inhibition	Osmani et al. (1978)
Mentha arvensis	Plant oil	*An. stephensi*	Larvicidal	Kumar and Dutta (1987)
Nepeta cataria	Stems, leaves, roots, flowers	*Ae. aegypti*	Larvicidal	Patterson et al. (1975)
Ocimum americanum	Whole plants	*Ae. aegypti*	Ovipositional deterrent	Sharma et al. (1981b)
O. basilicum	Whole plants, plant oil	*Cx. quinquefasciatus* *Ae. aegypti*	Larvicidal, repellent, reduction of adult emergence	Kalyanasundaram and Babu (1982), Chavan and Nikam (1982a), Chopra et al. (1941), Supavarn et al. (1974)
O. sanctum	Leaf oil	*Cx. quinquefasciatus*	Larvicidal, repellent	Chavan et al. (1983), Chopra et al. (1941), Rathore (1978)

Appendix 1. *Continued.*

Family and species[a]	Parts used	Mosquito species	Bioactivity	Reference
O. suave	Leaf oil	Mosquitoes	Repellent	Chogo and Crank (1981)
Origanum majorana	Whole plants	*Ae. aegypti*	Reduced adult emergence	Supavarn et al. (1974)
Pogostemon cablin	Whole plants	Mosquito larvae	Larvicidal	Jacobson (1958)
Rosmarinus officinalis	Whole plants	*Ae. aegypti*	Repellent	Thorsell (1988)
Salvia officinalis	Whole plants	*Ae. aegypti*	Growth inhibition	Supavarn et al. (1974)
Satureja hortensis				
Thymus serphylum				
LAURACEAE				
Sassafras albidum	Plant oil	*Aedes* species	Repellent	Jacobson (1958)
LECANORACEAE				
Lecanora rubina	Whole plants	*Aedes* species	Larvicidal	Jacobson (1958)
LEGUMINOSAE				
Amorpha fruticosa	Seed coat, fruits	*Ae. aegypti* *Ae. albopictus*	Larvicidal, repellent, adulticidal	Jacobson (1958)
Astragalus canadensis	Stems, leaves, roots, flowers, fruits	*Ae. aegypti*	Larvicidal	Patterson et al. (1975)
Butea frondosa	Seeds	Mosquito larvae	Larvicidal	Jacobson (1958)
Caesalpinia peltophoroides	Stems, leaves	*Ae. fluviatilis*	Ovipositional deterrent	Consoli et al. (1989)
Cassia alata	Leaves	Mosquito larvae	Larvicidal	Jacobson (1958)
C. holosericea	Whole plants	*Ae. aegypti*	Larvicidal, growth inhibition	Qureshi et al. (1986)
C. spectabilis	Leaves	Mosquito larvae	Larvicidal	Jacobson (1958)
Dalbergia retusa	Wood extract	Mosquito larvae	Growth inhibition	Jurd and Manners (1980)
Derris elliptica	Fresh and dry roots	*Ae. aegypti* *Cx. pipiens*	Larvicidal	Ameen et al. (1983, 1985), Jacobson (1958)
Desmodium caudatum	Leaves	*Cx. pipiens*	Larvicidal	Jacobson (1958)
Dolichos buchani	Roots	*Aedes* species	Larvicidal	Jacobson (1958)
Erythrophleum couminga	Bark	*Anopheles* species	Larvicidal	Jacobson (1958)
Gliricidia sepium	Flower clusters, leaves, ripe fruits, roots	Mosquito larvae	Larvicidal	Jacobson (1958)

Indigofera suffruticosa	Some plant parts as dusts, extracts	Mosquito larvae	Larvicidal	Jacobson (1958)
Muelleria frutescens	Fruits	*Aedes* species	Larvicidal	Jacobson (1958)
Pachyrhizus erosus	Leaves, seeds	*Aedes* species	Larvicidal	Jacobson (1958)
Piscidia piscipula	Roots, bark, root wood	*Aedes* species *Anopheles* species	Larvicidal	Jacobson (1958)
Poinciana regia	Flowers, leaves	*Ae. fluviatilis*	Ovipositional deterrent	Consoli et al. (1989)
Sophora flavescens	Roots	*Cx. pipiens*	Larvicidal	Jacobson (1958)
Spatholobus roxburghii	Bark	Mosquito larvae	Larvicidal	Jacobson (1958)
Swartzia madagascariensis	Fruit pods	*An. gambiae* *Ae. aegypti*	Larvicidal	Minijas and Sarda (1986)
Trifolium species	Seeds	*Cx. quinquefasciatus*	Larvicidal	Hartzell (1947)
LEMNACEAE				
Lemna minor	Whole plants	*Ae. aegypti*	Larvicidal, ovipositional deterrent	Angerilli (1980), Judd and Borden (1980)
LENTIBULARIACEAE				
Urticularia minor	Whole plants	*Ae. aegypti*	Larvicidal	Angerilli (1980)
LESSONIACEAE				
Macrocystis pyrifera	Whole plants	*Cx. quinquefasciatus*	Larvicidal, growth inhibition, repellent	Sherif and Hall (1985)
Microcystis aeruginosa	Whole plants	*Cx. pipiens* *Ae. aegypti* *Cs. longiareolata*	Larvicidal	Ilyaletdinova and Dubitskii (1974)
LILIACEAE				
Allium canadense	Whole plants	*Ae. aegypti*	Larvicidal	Supavarn et al. (1974)
A. sativum	Stems, oil of rhizomes and cloves	*Ae. fluviatilis* *Cx. stigmatosoma* *Cx. tarsalis* *Ae. aegypti* *Ae. triseriatus* *Ae. sierrensis* *Ae. nigromaculis*	Larvicidal	Consoli et al. (1988), Amonkar and Reeves (1970), Debkirtaniya et al. (1980)
A. schoenoprasum	Whole plants	*Ae. aegypti* *Cx. quinquefasciatus*	Larvicidal, reduction of adult emergence	Supavarn et al. (1974), Hartzell and Wilcoxon (1941)
A. scorodoprasum	Roots, stems	*Cx. pipiens*	Larvicidal	Jacobson (1958)
A. vineale	Whole plants	*Ae. aegypti*	Larvicidal, growth inhibition	Supavarn et al. (1974)
Aloe puridens	Roots	*Ae. aegypti*	Larvicidal	Confalone et al. (1983)
Amiantheum muscaetoxicum	Bulbs	*Aedes* species	Larvicidal	Jacobson (1958)

Appendix 1. *Continued.*

Family and species[a]	Parts used	Mosquito species	Bioactivity	Reference
Colchicum autumnale	Seeds	*Cx. quinquefasciatus*	Larvicidal	Hartzell (1947)
Schoenocaulon officinale	Seeds	*Cx. quinquefasciatus*	Larvicidal	Hartzell (1947)
Veratrum album	Whole plants	Mosquitoes	Adulticidal	Jacobson (1958)
V. dachuricum				
V. nigrum				
V. stamineum	Roots, stems	*Cx. pipiens*	Larvicidal	Jacobson (1958)
Zigadenus paniculatus	Bulbs	*Aedes* species	Larvicidal	Jacobson (1958)
LINACEAE				
Linum usitatissimum	Seeds	*Cx. quinquefasciatus*	Larvicidal	Banu and Nurul-Huda (1983)
LOGANIACEAE				
Spigelia anthelmia	Some plant parts as dusts, extracts	Mosquito larvae	Larvicidal	Jacobson (1958)
LORANTHACEAE				
Phoradendron flavescens	Leaves	*Cx. quinquefasciatus*	Larvicidal	Hartzell (1947)
MAGNOLIACEAE				
Liriodendron tulipifera	Leaves	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
MALPIGHIACEAE				
Tetrapteris acutifolia	Some plant parts as dusts, extract	Mosquito larvae	Larvicidal	Jacobson (1958)
MALVACEAE				
Hibiscus abelmoschus	Seeds	*Cx. quinquefasciatus*	Larvicidal	Hartzell (1947)
MELASTOMATACEAE				
Tibouchina scrobiculata	Leaves	*Ae. fluviatilis*	Larvicidal	Consoli et al. (1988)
MELIACEAE				
Azadirachta indica	Whole plants, leaves, seeds, kernels	*Cx. pipiens* *Cx. quinquefasciatus* *Ae. aegypti* *Ae. togoi* *An. stephensi*	Larvicidal (synergist), growth inhibition	Chavan et al. (1979), Kalyanasundaram and Babu (1982), Zebitz (1984, 1986), Schmutterer and Zebitz (1984), Ermel et al. (1984), Siddiqui et al. (1986, 1988), Naqvi (1987)
Melia azadirachta	Plant oil	*Anopheles* species	Larvicidal	Kumar and Dutta (1987)

M. volkensi	Fruit kernels, dry fruits	*An. arabiensis* *Ae. aegypti*	Larvicidal, growth inhibition	Mwangi and Mukiama (1988), Mwangi and Rembold (1988)
MENISPERMACEAE				
Menispermum canadense	Stems, leaves, roots	*Ae. aegypti*	Larvicidal	Patterson et al. (1975)
MONILIACEAE				
Verticillum bassiana	Whole plants	Mosquito larvae	Larvicidal	Suzuki et al. (1977)
MONOMIACEAE				
Atherosperma moschatum	Plant oil	*Aedes* species	Repellent	Jacobson (1958)
MYOPORACEAE				
Bontia daphanoides	Some plant parts as dusts, extracts	Mosquito larvae	Larvicidal	Jacobson (1958)
MYRICACEAE				
Myrica gale	Whole plants	*Ae. aegypti*	Repellent	Thorsell et al. (1970)
MYRTACEAE				
Backhousia myrtifolia	Plant oil	*Aedes* species *Anopheles* species	Repellent	Jacobson (1958)
Eucalyptus botryoides	Leaves, plant oil	*Ae. punctor*	Adulticidal, repellent	Jacobson (1958)
E. dumosa		*Aedes* species		
E. globulus	Plant oil	*Cx. quinquefasciatus* *An. stephensi*	Larvicidal, repellent	Chavan et al. (1983), Osmani et al. (1972)
E. saligna	Plant oil	Mosquito	Adulticidal	Kambu et al. (1982)
Eugenia caryophyllata	Flower buds	Mosquito larvae *An. stephensi*	Larvicidal	Jacobson (1958), Kumar and Dutta (1987)
E. haitiensis	Leaf oil	Mosquitoes	Adulticidal	Jacobson (1958)
Melaleuca bracteata	Plant oil	*Aedes* species	Repellent	Jacobson (1958)
Pimenta acris	Leaf oil	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
NOSTOCACEAE				
Anabena variabilis	Whole plant	*Cx. pipiens* *Ae. aegypti* *Cs. longiareolata*	Larvicidal	Ilyaletidinova and Dubitskii (1974)
NYMPHACEAE				
Nymphaea tuberosa	Whole plants	*Ae. aegypti*	Larvicidal, ovipositional deterrent	Angerilli (1980)
OLEACEAE				
Chionanthus virginica	Bark of roots	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)

Appendix 1. *Continued.*

Family and species[a]	Parts used	Mosquito species	Bioactivity	Reference
OOCYSTACEAE				
Chlorella ellipsoidea	Whole plant	*Cx. quinquefasciatus* *Cs. incidens* *Ae. aegypti*	Larvicidal, growth inhibition	Dhillon et al. (1982)
PAPAVERACEAE				
Bocconia cordata	Leaves	*Cx. pipiens*	Larvicidal	Jacobson (1958)
Papaver species	Flowers, stems	Mosquito larvae	Larvicidal	Jacobson (1958)
Sanguinaria canadensis	Stems, leaves, roots, rhizomes	*Ae. aegypti*	Larvicidal, growth inhibition	Patterson et al. (1975)
PEDALIACEAE				
Pedalium murax	Whole plants	*Ae. aegypti* *Cx. quinquefasciatus* *An. stephensi*	Larvicidal	Kalyanasundaram and Das (1985)
PHRYMACEAE				
Phryma leptostachya	Stems, leaves, roots, rhizomes, flowers, fruits	*Ae. aegypti*	Larvicidal, growth inhibition	Patterson et al. (1975)
P. oblongifolia	Leaves, stems, roots	*Cx. pipiens*	Larvicidal	Jacobson (1958)
PHYTOLACCACEAE				
Petiveria alliacea	Some plant parts as dusts, extracts	Mosquito larvae	Larvicidal	Jacobson (1958)
Phytolacca dodecandra	Endod extract	*Ae. aegypti* *An. quadrimaculatus* *Cx. pipiens*	Larvicidal	Spielman and Lemma (1973)
PINACEAE				
Callitris glauca	Wood oil	*Aedes* species	Repellent	Jacobson (1958)
Cedrus deodara	Plant oil	*An. stephensi*	Larvicidal	Singh et al. (1984)
Cupressus semipervirens	Leaves	*Ae. fluviatilis*	Ovipositional attractant	Consoli et al. (1989)
Juniperus species	Berries, oil	*Cx. quinquefasciatus* Mosquitoes	Larvicidal, repellent	Hartzell and Wilcoxon (1941)

J. recurva	Heartwood, oil	*Cx. pipiens pallens* *Ae. vexans* *Ae. sticticus* *Anopheles* species	Larvicidal, repellent, adulticidal	Oda et al. (1977), Novak and Potucek (1977), Novak (1985)
Pinus and *Picea*	Resin	*Cx. pipiens*	Growth inhibition	Paulov and Paulovova (1980), Hartzell (1948), Novak (1968, 1985)
Pinus excelsa	Resin seeds	*Cx. pipiens*	Larvicidal	
P. taeda		*Cx. quinquefasciatus*		
P. virginiana				
Thuja plicata	Thujic acid	*Ae. aegypti*	Repellent	Hach and McDonald (1971)
PIPERACEAE				
Piper cubeb	Berries, fruits, seeds, leaves	*Cx. quinquefasciatus* *Ae. aegypti* *Aedes* species *Anopheles* species	Larvicidal, adulticidal	Hartzell (1944), Jacobson (1958), Novak (1968, 1985), Srivastava (1970), Addae-Mensah and Achieng (1986)
P. longum				
P. nigrum				
P. novaehollandiae				
P. peepuloides				
P. tuberculatum				
P. guineense				
PLOCAMIACEAE				
Plocamium telfairiae	Whole plants	*Cx. pipiens pallens*	Larvicidal	Watanabe et al. (1989)
POLYGONACEAE				
Polygonum coccineum	Stems, leaves, roots, flowers	*Ae. aegypti*	Larvicidal, growth inhibition	Patterson et al. (1975)
Rumex crispus	Whole plants	*Ae. aegypti*	Grown inhibition, reduction of adult emergence	Supavarn et al. (1974)
Rheum officinale	Buds	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
POLYPODIACEAE				
Aspidium filix-mas	Rhizomes	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
RANUNCULACEAE				
Acontium barbatum	Fruits, flowers, stems, roots	*Anopheles* species *Culex* species	Larvicidal, adulticidal	Jacobson (1958)
A. japonicum				
Anemone altaica	Fresh plants	Mosquitoes	Adulticidal	Jacobson (1958)
Clematis apifolia	Leaves	*Cx. pipiens*	Larvicidal	Jacobson (1958)
Coptis trifolia	Whole plants	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
Delphinium ajacis	Seeds, seed oil, flowers, fruits	*Cx. quinquefasciatus* *Anopheles* species	Larvicidal, adulticidal, repellent	Hartzell (1944), Jacobson (1958)
D. browni				
D. cheilanthus				

Appendix 1. *Continued.*

Family and species[a]	Parts used	Mosquito species	Bioactivity	Reference
D. dictyocarpum *D. elatum* *D. grandiflorum* *D. laxiflorum* *D. retropilosum*				
Ranunculus aquatilis	Whole plants	*Ae. aegypti*	Larvicidal, ovipositional attractant	Angerilli (1980)
R. macounii	Stems, leaves, roots	*Ae. aegypti*	Larvicidal, growth inhibition	Patterson et al. (1975)
Nigella species	Seeds	*Cx. pipiens*	Larvicidal	Gayar and Shazli (1968)
RHIZOPHORACEAE				
Rhizophora apiculata	Stilt roots	*An. stephensi*	Larvicidal	Thangam and Kathiresan (1988a)
ROSACEAE				
Prunus laurocerasus *P. maacki* *P. padus*	Leaves, flowers, bark, fresh plants	*Anopheles* species *Aedes* species *Ae. punctor*	Adulticidal	Jacobson (1958)
RUBIACEAE				
Gardenia lutea *Randia nilotica*	Whole plants	Mosquito larvae	Larvicidal	Zarroug et al. (1988)
RUTACEAE				
Citrus medica	Leaves, stems, roots, seeds	*An. stephensi*	Larvicidal	Sujatha et al. (1988)
Clausena anisata	Dried plants	Mosquitoes	Repellent	Okunade and Olaifa (1987)
Fagara macrophylla	Isobutylamides from plant	*Cx. pipiens*	Larvicidal, growth inhibition	Kubo et al. (1984)
F. mantchurica	Fruits	*Cx. pipiens*	Larvicidal	Jacobson (1958)
Haplophyllum tuberculatum	Aerial parts	*Cx. quinquefasciatus*	Larvicidal, ovicidal, pupicidal, growth inhibition	Mohsen et al. (1989)
Phellodendron amurense	Fruits and bark	*Cx. pipiens*	Larvicidal	Haller (1940)
Pilocarpus microphyllus *P. jaborandii*	Leaves	*Cx. quinquefasciatus*	Larvicidal	Hartzell (1947)
Ruta graveolens	Whole plants	*Cx. quinquefasciatus*	Larvicidal	Hartzell (1947),

Xanthoxylum species	Berries	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
Zanthoxylum clava-herculis	Bark, root bark	*Cx. pipiens*	Larvicidal	Jacobson (1958)
Z. piperitum				
Zieria smithii	Plant oil	*Aedes* species *Anopheles* species	Repellent	Jacobson (1958)
SALIACACEAE				
Populus species	Buds	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
SANTALACEAE				
Santalum album	Wood, wood oil	*Cx. quinquefasciatus*	Larvicidal, repellent	Hartzell (1944), Osmani et al. (1972)
SAPINDACEAE				
Koelreuteria paniculata	Seeds, leaves	*Cx. quinquefasciatus*	Larvicidal	Hartzell (1947)
Paullinia fuscescens	Some plant parts as dusts, extracts	Mosquito larvae	Larvicidal	Jacobson (1958)
Sapindus saponaria	Seeds, fruits	Mosquito larvae	Larvicidal	Jacobson (1958)
SAPOTACEAE				
Madhuca longifolia	Leaves, stems, seeds, roots	*Cx. quinquefasciatus* *Ae. aegypti* *An. stephensi*	Larvicidal, growth inhibition	Sujatha et al. (1988)
SAXIFRAGACEAE				
Astilbe species	Whole plants	*Cx. quinquefasciatus*	Larvicidal	Hartzell (1947)
Hydrangea arborescens	Roots	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
SCROPHULARIACEAE				
Digitalis purpurea	Digitonin from plants	*Ae. aegypti*	Growth inhibition	Harley (1967)
Scrophularia lanceolata	Stems, leaves, roots	*Ae. aegypti*	Larvicidal, growth inhibition	Patterson et al. (1975)
Verbascum blattaria	Whole plants	*Ae. aegypti*	Larvicidal	Supavarn et al. (1974)
SCYTIOSIPHONACEAE				
Haplosiphon fontinalis	Whole plants	*Cx. pipiens* *Ae. aegypti* *Cs. longiareolata*	Larvicidal	Ilyaletdinova and Dubitskii (1974)
SIMAROUBACEAE				
Balanites aegyptiaca	Whole plants	Mosquito larvae	Larvicidal	Zarroug et al. (1988)
Picrolemma pseudocoffea	Stems, roots	*Aedes* species	Larvicidal	Jacobson (1958)
Quassia amara	Leaves	*Cx. quinquefasciatus*	Larvicidal	Evans and Kaleysa Raj (1988)

Appendix 1. *Continued.*

Family and species[a]	Parts used	Mosquito species	Bioactivity	Reference
SOLANACEAE				
Capsicum frutescens	Pods	*Cx. quinquefasciatus*	Larvicidal	Hartzell (1947)
Datura candida	Some plant parts as dusts, extracts	Mosquito larvae	Larvicidal	Jacobson (1958)
D. stramonium	Seeds	*Cx. pipiens*	Larvicidal	Gayar and Shazli (1968)
Lycopersicon lycopersicun	Whole plants, tomatine alkaloid	*Ae. aegypti*	Repellent, growth inhibition	Harley (1967), Thorsell et al. (1970)
Nicotiana rustica	Leaves	*Cx. pipiens*	Larvicidal	El Gayar et al. (1975)
STEMONACEAE				
Stemona japonica	Roots	*Cx. pipiens*	Larvicidal	Jacobson (1958)
STYRACEAE				
Benzoin aestivale	Buds	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
Styrax japonica	Fruits	*Cx. pipiens*	Larvicidal	Jacobson (1958)
SYMPLOCACEAE				
Symplocos tinctoria	Stems	Mosquito larvae	Larvicidal	Jacobson (1958)
THEACEAE				
Camellia japonica	Leaves	*Cx. quinquefasciatus*	Larvicidal	Hartzell (1947)
THYMELAEACEAE				
Lasiosiphon eriocephalus	Whole plants	*Cx. quinquefasciatus*	Larvicidal	Chavan and Nikam (1982b)
UMBELLIFERAE				
Anethum graveolens	Whole plants	*Ae. aegypti*	Growth inhibition	Supavarn et al. (1974)
Anthriscus sylvestris	Roots	*Cx. pipiens* *Cx. pipiens pallens*	Larvicidal	Kozawa et al. (1982), Inamori et al. (1986a, 1986b)
Carum carvi	Seeds	*Cx. quinquefasciatus*	Larvicidal	Hartzell and Wilcoxon (1941)
Conium maculatum	Whole plants	*Ae. aegypti*	Reduction of adult emergence	Supavarn et al. (1974)
Coriandrum sativum	Fruits, leaves	*Ae. fluviatilis*	Larvicidal, ovipositional attractant	Consoli et al. (1988, 1989)
Foeniculum vulgare	Seeds, leaves	*Cx. quinquefasciatus* *Ae. fluviatilis*	Larvicidal, ovipositional attractant	Hartzell (1944), Consoli et al. (1989)
Gymnophyton isatidicarpum		*Cx. pipiens*	Growth inhibition	Torres et al. (1979)
Peucedanum ostruthium	Roots	*Cx. quinquefasciatus*	Larvicidal	Jacobson (1958)
Pimpinella anisum	Seeds, whole plants	*Cx. quinquefasciatus* *Ae. aegypti*	Larvicidal, growth inhibition	Hartzell (1944), Supavarn et al. (1974), Craig (1981)

Sium suave	Stems, leaves, fruits, flowers, roots	*Ae. aegypti*	Larvicidal	Patterson et al. (1975)
VERBENACEAE				
Avicinenia marina	Whole plants	*An. stephensi*	Larvicidal	Thangam and Kathiresan (1988a)
Clerodendron inerme	Leaves	*Cx. pipiens*	Larvicidal	Gayar and Shazli (1968)
Duranta repens	Berries, fresh leaves	Mosquito larvae *Cx. pipiens*	Larvicidal, adulticidal	Jacobson (1958), El-Nagger and Mosallam (1987)
Lantana camara	Whole plants, leaves, leaf oil	*Cx. quinquefasciatus* *Cx. pipiens* mosquitoes	Larvicidal (synergist), repellent	Kalyanasundaram and Babu (1982), Chavan and Nikam (1982c), Attri and Singh (1978)
Vitex negundo	Whole plants	*Cx. quinquefasciatus*	Larvicidal (synergist)	Kalyanasundaram and Babu (1982)
ZINGIBERACEAE				
Curcuma longa	Rhizomes (paste)	*Anopheles* species	Repellent	Philip et al. (1945)
ZYGNEMATACEAE				
Spirogyra nitida	Whole plants	*Cx. quinquefasciatus*	Larvicidal, growth inhibition	Sherif and Hall (1985)